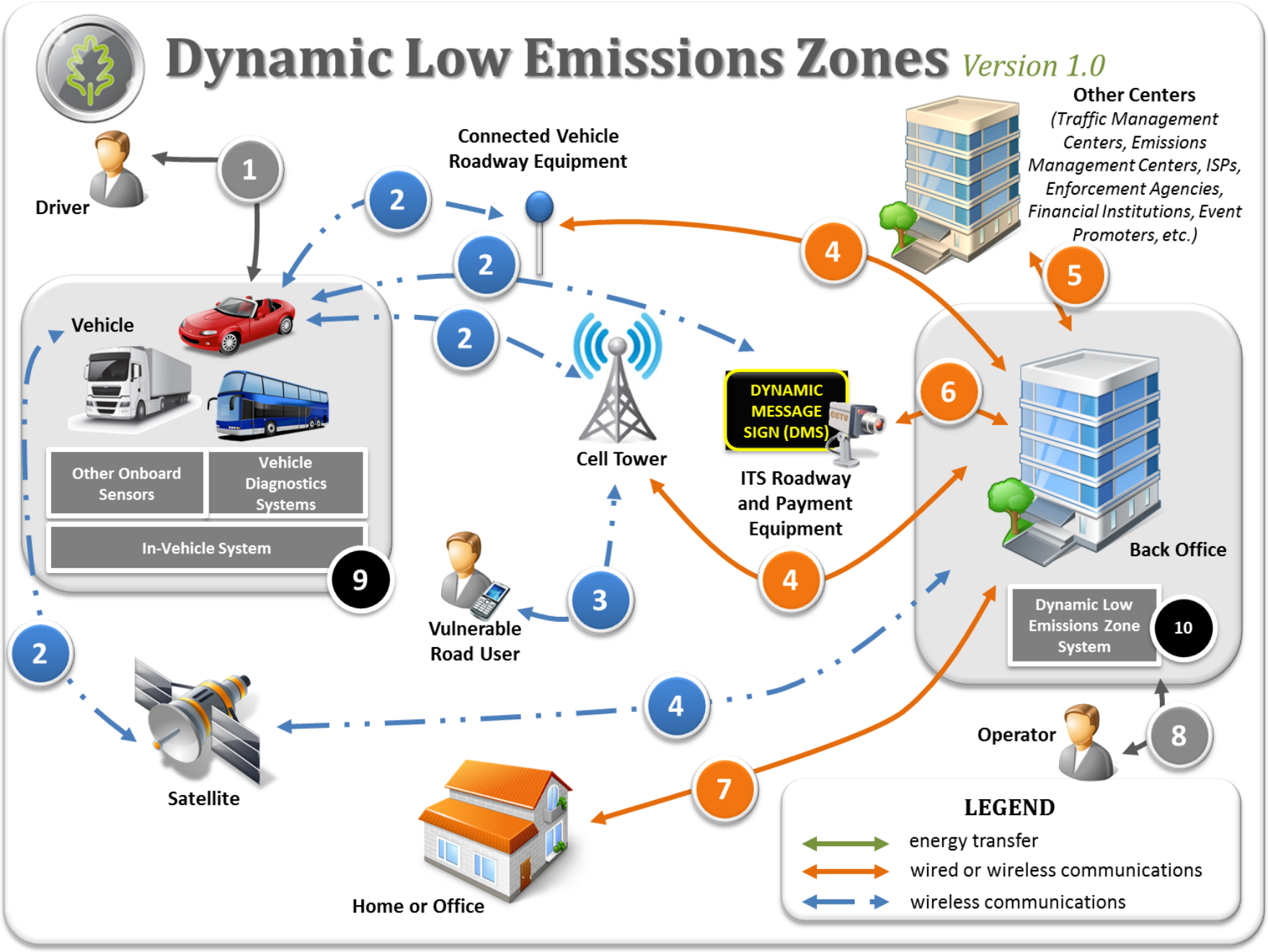
Dynamic Low Emissions Zones Version 1.0
Driver
1
Connected Vehicle Roadway Equipment
2
Other Centers
(Traffic Management Centers, Emissions Management Centers, ISPs, Enforcement Agencies, Financial Institutions, Event Promoters, etc.)
4
5
Vehicle
Other Onboard Sensors
Vehicle Diagnostics Systems
In-Vehicle System
9
Cell Tower
DYNAMIC MESSAGE SIGN (DMS)
ITS Roadway and Payment Equipment
6
Back Office
Dynamic Low Emissions Zone System
10
Vulnerable Road User
3
Satellite
Operator
8
7
Home or Office
LEGEND
energy transfer
wired or wireless communications
wireless communications

Dynamic Low Emissions Zones Transformative Concept

The Dynamic Low Emissions Zone Transformative Concept includes a geographically defined area that seeks to restrict or deter access by specific categories of high-polluting vehicles to improve the air quality within the geographic area. The low emissions zone can be dynamic, allowing the operating entity to change the location, boundaries, fees, or the time the low emissions zone will be established and its duration. At the heart of this Transformative Concept is a Dynamic Emissions Pricing application, which leverages connected vehicle technologies to dynamically determine fees or incentives for vehicles entering the low-emissions zone. These fees or incentives may be based on the vehicle's engine emissions standard or emissions data collected directly from the vehicle using V2I communications. To encourage travelers entering the zone to use public transportation, policy can be in place to waive fees for transit vehicles entering the low-emissions zone or provide incentives to travelers using transit. The Dynamic Low Emissions Zones Transformative Concept features three applications:

- Dynamic Emissions Pricing
- Connected Eco-Driving
- Multi-Modal Traveler Information

This Transformative Concept also provides the capability for the Low Emissions Zone to be dynamic or allowing the operating entity to change the location or time of the Low Emissions Zone. For example, this would allow the Dynamic Low Emissions Zone be commissioned based on various criteria including atmospheric conditions, weather conditions, or special events.

Pre-trip and en-route traveler information is also a critical component of this Transformative Concept. This includes information about criteria for vehicles to enter the Low Emissions Zone, expected fees and incentives for their trip, current and predictive traffic conditions, and the geographic boundaries of the Low Emissions Zone. Finally, Connected Eco-Driving applications are encouraged inside the Low Emissions Zone. Once inside the Low Emissions Zone, if real-time data from the vehicle shows that it is being driven in a manner that reduces emissions (i.e., practicing eco-driving tactics); the driver could be given an economic reward.

Breakout Session Questions

1. Does the Data Flow Diagram accurately depict the Transformative Concept?
2. Do you agree with the data being exchanged between the actors?
3. Is there any data identified in the read-ahead package that is unlikely to be exchanged between actors?
4. Is there any data that should be exchanged between actors that is not identified in the read-ahead package?
5. Based on what you heard about the Dynamic Low Emissions Zones Transformative Concept, what aspect stands out? What is useful to you as a deployer or operator? Are there components of this Transformative Concept that you would consider implementing in the next 5 years? 10 years? 20 years?
6. How can incentives be introduced into this Transformative Concept to encourage "green" choices from travelers entering the Low Emissions Zone? What would these incentives be and how would they be determined? Which strategy – providing incentives or fees – would be more effective?
7. Transit and freight operations are important components of a successful Dynamic Low Emissions Zone Transformative Concept. How can transit operations be supported by this Transformative Concept? How can this Transformative Concept be implemented to minimize negative effects on freight operations?
8. What geographic areas do you foresee Dynamic Low Emissions Zones likely being implemented? (examples may include event venues, around ports, etc.)
9. How can an operating entity ensure that travelers are provided a steady stream of information regarding the Dynamic Low Emissions Zone allowing them to make informed, "green" transportation decisions?

Table 1. Dynamic Low Emissions Zones Data Flows and Actions

ID	ACTORS	DATA FLOW / ACTION	RELATED USER NEEDS
1	**In-Vehicle System and Driver**	<u>In-Vehicle System sends to Driver</u> • Dynamic Low Emissions Zone parameters (e.g., location, duration, fee structure, and other characteristics about the Low Emissions Zone) • Eco-driving recommendations (e.g., recommended driving speeds, driver feedback, etc.) • Multi-modal options • Traffic conditions • Environmental conditions (e.g., code red air quality alerts) • Road weather conditions • Incentive received (or fee paid) • Financial information • Notice of violation <u>Driver Sends to In-Vehicle System</u> • Activation of Application (e.g., activate eco-driving application, activate incentive application) • Updates to configurable parameters for Low Emissions Zone access, fees, and/or incentives • Origin-Destination (O-D) information	• IVS-DC-01: Collected Driver Input • IVS-D-01: Provide Traffic Conditions to the Driver • IVS-D-02: Provide Environmental Conditions to the Driver • IVS-D-03: Provide Dynamic Low Emissions Zone Parameters to the Driver • IVS-D-04: Provide Trip/Route Information to the Driver • IVS-D-05: Provide Eco-Driving information to the Driver • IVS-DI-01: Provide Driver Interface
2	**In-Vehicle System and Connected Vehicle Roadway Equipment** **In-Vehicle System and Cell Tower**	<u>In-Vehicle System sends to Connected Vehicle Roadway Equipment, Cell Tower, and Satellite</u> • Vehicle status data (e.g., BSM data including vehicle's location, heading, speed, acceleration, braking status, size, etc.) • Vehicle status environmental data (e.g., BEM data including the vehicle's fuel type, engine type, current emissions, average emissions, current fuel consumption, and average fuel consumption) • Vehicle specific data (e.g., vehicle's make and model, engine type, number of axles, average emissions, average fuel consumption,	• IVS-DC-02: Receive Traffic Conditions Data • IVS-DC-03: Receive Environmental Conditions Data • IVS-DC-04: Receive Dynamic Low Emissions Zone Parameter Data • IVS-DC-05: Receive Payment or Incentive Request Information • IVS-DC-06: Receive Confirmation of

ID	ACTORS	DATA FLOW / ACTION	RELATED USER NEEDS
	In-Vehicle System and Satellite	unique identifier (license plate number or vehicle registration data), the time the vehicle entered the Low Emissions Zone, and number of miles traveled within the Low Emissions Zone) • Incentive / payment data <u>Connected Vehicle Roadway Equipment, Cell Tower, and Satellite sends to the In-Vehicle System</u> • Traffic conditions (e.g., link speeds, queues, incidents, travel times, etc.) • Environmental conditions (e.g., air quality information, code red air quality alerts) • Road weather conditions (e.g., pavement conditions) • Dynamic Low Emissions Zone parameters (e.g., location, duration, fee structure, and other characteristics about the Low Emissions Zone) • Request for electronic payment or incentive • Confirmation of payment or incentive • Notice of violation	Payment or Incentive • IVS-DC-07: Receive Notice of Violation • IVS-D-06: Disseminate Payment / Incentive Data • IVS-D-07: Disseminate Vehicle Status Data • IVS-D-08: Disseminate Vehicle Status Environmental Data
	**Cell Tower and Vulnerable Road User**	<u>Cell Tower to Vulnerable Road User</u> • Dynamic Low Emissions Zone parameters (e.g., location, duration, fee structure, and other characteristics about the Low Emissions Zone) • Traffic conditions (e.g., link speeds, queues, incidents, travel times, etc.) • Multi-modal travel options • Environmental conditions (e.g., air quality information, code red air quality alerts)	• DLEZS-DC-02: Disseminate Low Emissions Zone Parameters to Other Centers and Travelers • DLEZS-DC-03: Disseminate Traffic Conditions to Other Centers and Travelers • DLEZS-DC-05: Disseminate Multi-Modal Travel Options • DLEZS-DC-06: Disseminate Environmental Conditions to Other Centers and Travelers

ID	ACTORS	DATA FLOW / ACTION	RELATED USER NEEDS
	**Connected Vehicle Roadway Equipment and Dynamic Low Emissions Zone System** **Cell Tower and Dynamic Low Emissions Zone System** **Satellite and Dynamic Low Emissions Zone System**	<u>Connected Vehicle Roadway Equipment, Cell Tower, and Satellite sends to Dynamic Low Emissions Zone System</u> • Vehicle status data (e.g., vehicle's location, heading, speed, acceleration, braking status, size, etc.) • Vehicle status environmental data (e.g., BEM data including the vehicle's fuel type, engine type, current emissions, average emissions, current fuel consumption, and average fuel consumption) • Vehicle specific data (e.g., vehicle's make and model, engine type, number of axles, average emissions, average fuel consumption, unique identifier (license plate number or vehicle registration data), the time the vehicle entered the Low Emissions Zone, and number of miles traveled within the Low Emissions Zone) • Electronic payment or incentive <u>Dynamic Low Emissions Zone System sends to Connected Vehicle Roadway Equipment, Cell Tower, and Satellite</u> • Dynamic Low Emissions Zone parameters (e.g., location, duration, fee structure, and other characteristics about the Low Emissions Zone) • Traffic conditions (e.g., link speeds, queues, incidents, travel times, etc.) • Multi-modal travel options • Environmental conditions (e.g., air quality information, code red air quality alerts) • Road weather conditions (e.g., pavement conditions) • Request for electronic payment or incentive • Confirmation of payment or incentive • Notice of violation	• DLEZS-DC-03: Collect Traffic Data • DLEZS-DC-04: Collect Environmental Data • DLEZS-DC-06: Collect Vehicle Specific Data • DLEZS-DC-06: Collect Electronic Payments • DLEZS-D-01: Disseminate Low Emissions Zone Parameters to Vehicles • DLEZS-D-04: Disseminate Traffic Conditions to Vehicles • DLEZS-D-05: Disseminate Multi-Modal Travel Options • DLEZS-D-07: Disseminate Environmental Conditions to Vehicles • DLEZS-D-08: Disseminate Information for Request for Electronic Payment to Vehicles • DLEZS-D-10: Provide Incentives • DLEZS-D-11: Provide Confirmation of Payment or Incentive to Individual Vehicles • DLEZS-D-12: Provide Notice of Violation to Vehicles

ID	ACTORS	DATA FLOW / ACTION	RELATED USER NEEDS
5	**Dynamic Low Emissions Zone System and Other Centers**	<u>Dynamic Low Emissions Zone System sends to Other Centers</u> • Dynamic Low Emissions Zone parameters (e.g., location, duration, fee structure, and other characteristics about the Low Emissions Zone) • Traffic conditions (e.g., link speeds, queues, incidents, travel times, etc.) • Multi-modal travel options • Traffic signal timing plans in operation • Environmental conditions (e.g., air quality data, code red air quality alerts) • Road weather data (e.g., road conditions) • Financial data – sent to Financial Institutions • Violation data – sent to Enforcement Agencies <u>Other Centers sends to Dynamic Low Emissions Zone System</u> • Special event data • Transit operations data (e.g., transit routes) • Traffic conditions (e.g., link speeds, queues, incidents, travel times, etc.) • Environmental conditions (e.g., air quality data, code red air quality alerts) • Road weather data (e.g., road conditions) • Financial data - sent from Financial Institutions • Violation data – sent from Enforcement Agencies	• DLEZS-DC-01: Collect Special Event Data • DLEZS-DC-02: Collect Transit Operations Data • DLEZS-DC-03: Collect Traffic Data • DLEZS-DC-04: Collect Environmental Data • DLEZS-D-01: Disseminate Low Emissions Zone Parameters to Other Centers and Travelers • DLEZS-D-03: Disseminate Traffic Conditions to Other Centers and Travelers • DLEZS-D-06: Disseminate Environmental Conditions to Other Centers and Travelers • DLEZS-D-09: Request for Payment from Financial Institutions • DLEZS-D-13: Notify Enforcement Agencies of Violations
6	**ITS Roadway Equipment and Dynamic Low Emissions Zone System**	<u>ITS Roadway Equipment sends to Dynamic Low Emissions Zone System</u> • Traffic data (e.g., speed, volume, occupancy, travel times, etc.) • Environmental data (e.g., air quality data, etc.) • Road weather data (e.g., road friction, precipitation, temperature, etc.) • Vehicle specific data – sent using conventional toll tag readers (e.g., vehicle's make and model, engine type, number of axles,	• DLEZS-DC-03: Collect Traffic Data • DLEZS-DC-04: Collect Environmental Data • DLEZS-DC-06: Collect Vehicle Specific Data • DLEZS-DC-07: Collect Electronic

ID	ACTORS	DATA FLOW / ACTION	RELATED USER NEEDS
		average emissions, average fuel consumption, unique identifier (license plate number or vehicle registration data)) • Electronic payment data Dynamic Low Emissions Zone System sends to ITS Roadway Equipment • Dynamic Low Emissions Zone parameters – sent to DMS (e.g., fees and rules for using the Low Emissions Zone) • ITS device control functionality (e.g., control of DMS, cameras, etc.)	Payments
	**Dynamic Low Emissions Zone System and Home/Office**	Dynamic Low Emissions Zone System send to Home/Office • Dynamic Low Emissions Zone parameters (e.g., location, duration, fee structure, and other characteristics about the Low Emissions Zone) • Traffic conditions (e.g., link speeds, queues, incidents, travel times, etc.) • Multi-modal travel options • Environmental conditions (e.g., air quality information, code red air quality alerts) • Confirmation of payment or incentive • Notice of violation	• DLEZS-DC-02: Disseminate Low Emissions Zone Parameters to Other Centers and Travelers • DLEZS-DC-03: Disseminate Traffic Conditions to Other Centers and Travelers • DLEZS-DC-05: Disseminate Multi-Modal Travel Options • DLEZS-DC-06: Disseminate Environmental Conditions to Other Centers and Travelers
	**Dynamic Low Emissions Zone System and Operator**	Dynamic Low Emissions Zone System sends to Operator • Low Emissions Zone parameters and operational status • Traffic conditions • Environmental conditions • Road weather conditions • Multi-modal travel options • Performance measures • Archived data	• DLEZS-DC-05: Collect Operator Input • DLEZS-UI-01: User Interface

ID	ACTORS	DATA FLOW / ACTION	RELATED USER NEEDS
		Operator sends to Dynamic Low Emissions Zone System • Operator inputs (e.g., creating Low Emissions Zone, code red air quality alerts, or adding new equipment (e.g., new RSE units) to the system)	

9	**In-Vehicle System**	• Collect Data
		  ○ Dynamic Low Emissions Zone parameters (e.g., location, duration, fee structure, and other characteristics about the Low Emissions Zone)
		  ○ Driver input (e.g., activation of application, configurable parameters for Low Emissions Zone access, fees, and/or incentives, O-D information, etc.)
		  ○ Traffic conditions (e.g., link speeds, queues, incidents, travel times, etc.)
		  ○ Environmental conditions (e.g., air quality information, code red air quality alerts)
		  ○ Road weather conditions (e.g., pavement conditions)
		  ○ Dynamic Low Emissions Zone parameters (e.g., location, duration, fee structure, and other characteristics about the Low Emissions Zone)
		  ○ Request for electronic payment or incentive
		  ○ Confirmation of payment or incentive
		  ○ Notice of violation
		  ○ Vehicle diagnostics data (e.g., engine, emissions, GPS, vehicle type, unique identifier, etc.)
		• Process Data
		  ○ Process traffic conditions for presentation to driver
		  ○ Process environmental conditions for presentation to driver
		  ○ Determine alternative routes (e.g., routes around the Low Emissions Zone)
		  ○ Determine eco-driving recommendations (e.g., recommended speeds)
		  ○ Determine the vehicle's criteria for entering the Low Emissions Zone based on the parameters of the Low Emissions Zone
			• IVS-DC-01: Collect Driver Input
			• IVS-DC-02: Receive Traffic Conditions Data
			• IVS-DC-03: Receive Environmental Conditions Data
			• IVS-DC-04: Receive Dynamic Low Emissions Zone Parameter Data
			• IVS-DC-05: Receive Payment or Incentive Request Information
			• IVS-DC-06: Receive Confirmation of Payment or Incentive
			• IVS-DC-07: Receive Notice of Violation
			• IVS-DC-08: Collect Vehicle Diagnostics Data
			• IVS-DP-01: Process Traffic and Environmental Data for Traveler Information Messages
			• IVS-DP-02: Determine Trip/Route Options
			• IVS-DP-03: Determine Eco-Driving Recommendations
			• IVS-DP-04: Determine Vehicle's Criteria for Entering the Low Emissions Zone

ID	ACTORS	DATA FLOW / ACTION	RELATED USER NEEDS
		○ Determine vehicle emissions data (e.g., determine BEM for disseminate) ○ Manage payment of fees or collection of incentives • <u>Disseminate Data</u> ○ Electronic payment or incentive ○ Vehicle status data (e.g., BSM data including vehicle's location, heading, speed, acceleration, braking status, size, etc.) ○ Vehicle status environmental data (e.g., BEM data including the vehicle's fuel type, engine type, current emissions, average emissions, current fuel consumption, and average fuel consumption) ○ Vehicle specific data (e.g., vehicle's make and model, engine type, number of axles, average emissions, average fuel consumption, unique identifier (license plate number or vehicle registration data), the time the vehicle entered the Low Emissions Zone, and number of miles traveled within the Low Emissions Zone) • <u>Driver Interface</u> ○ Information to the driver ▪ Dynamic Low Emissions Zone parameters (e.g., location, duration, fee structure, and other characteristics about the Low Emissions Zone) ▪ Eco-driving recommendations (e.g., recommended driving speeds, driver feedback, etc.) ▪ Multi-modal options ▪ Traffic conditions ▪ Environmental conditions (e.g., code red air quality alerts) ▪ Road weather conditions ▪ Incentive received (or fee paid) ▪ Financial information ▪ Notice of violation ○ Activation of Application (e.g., activate eco-driving application, activate incentive application) ○ Updates to configurable parameters for Low Emissions Zone	• IVS-DP-05: Determine Vehicle Emissions Data • IVS-DP-06: Manage Fee Payment • IVS-D-01: Provide Traffic Conditions to the Driver • IVS-D-02: Provide Environmental Conditions to the Driver • IVS-D-03: Provide Dynamic Low Emissions Zone Parameters to the Driver • IVS-D-04: Provide Trip/Route Information to the Driver • IVS-D-05: Provide Eco-Driving Information to the Driver • IVS-D-06: Disseminate Payment/Incentive Data • IVS-D-07: Disseminate Vehicle Status Data • IVS-D-08: Disseminate Vehicle Status Environmental Data • IVS-DI-01: Provide Operator Interface

ID	ACTORS	DATA FLOW / ACTION	RELATED USER NEEDS
		access, fees, and/or incentives ○ Origin-Destination (O-D) information	
10	**Dynamic Low Emissions Zone System**	• <u>Collect Data</u> • Traffic data (e.g., speed, volume, occupancy, travel times, etc.) • Environmental data (e.g., air quality data, etc.) • Road weather data (e.g., road friction, precipitation, temperature, etc.) • Vehicle specific data – sent using conventional toll tag readers (e.g., vehicle's make and model, engine type, number of axles, average emissions, average fuel consumption, unique identifier (license plate number or vehicle registration data)) • Vehicle status data (e.g., vehicle's location, heading, speed, acceleration, braking status, size, etc.) • Vehicle status environmental data (e.g., BEM data including the vehicle's fuel type, engine type, current emissions, average emissions, current fuel consumption, and average fuel consumption) • Vehicle specific data (e.g., vehicle's make and model, engine type, number of axles, average emissions, average fuel consumption, unique identifier (license plate number or vehicle registration data), the time the vehicle entered the Low Emissions Zone, and number of miles traveled within the Low Emissions Zone) • Electronic payment or incentive data • <u>Process Data</u> ○ Process traffic data ○ Generate predicted traffic conditions ○ Process environmental data ○ Generate predicted emissions profile ○ Create and decommission Low Emissions Zones ○ Determine fees for vehicles ○ Determine incentives for vehicles ○ Detect and determine violations ○ Manage electronic payment processing	• DLEZS-DC-01: Collect Special Event Data • DLEZS-DC-02: Collect Transit Operations Data • DLEZS-DC-03: Collect Traffic Data • DLEZS-DC-04: Collect Environmental Data • DLEZS-DC-05: Collect Operator Input • DLEZS-DC-06: Collect Vehicle Specific Data • DLEZS-DC-07: Collect Electronic Payments • DLEZS-DP-01: Process Traffic Data • DLEZS-DP-02: Generate Predicted Traffic Conditions and Forecast Demand • DLEZS-DP-03: Process Environmental Data • DLEZS-DP-04: Generate Predicted Emissions Profile • DLEZS-DP-05: Create and Decommission Low Emissions Zones • DLEZS-DP-06: Determine Fees for Vehicles • DLEZS-DP-07: Determine Incentives for

ID	ACTORS	DATA FLOW / ACTION	RELATED USER NEEDS

		• Disseminate Data
		  ○ Dynamic Low Emissions Zone parameters (e.g., location, duration, fee structure, and other characteristics about the Low Emissions Zone)
		  ○ Traffic conditions (e.g., link speeds, queues, incidents, travel times, etc.)
		  ○ Multi-modal travel options
		  ○ Environmental conditions (e.g., air quality information, code red air quality alerts)
		  ○ Road weather conditions (e.g., pavement conditions)
		  ○ Request for electronic payment or incentive
		  ○ Confirmation of payment or incentive – sent to vehicles and travelers
		  ○ Notice of violation – sent to vehicles and travelers
		  ○ ITS device control functionality (e.g., control of DMS, cameras, etc.)
		  ○ Financial data – sent to Financial Institutions
		  ○ Violation data – sent to Enforcement Agencies
		• User Interface
		  ○ Low Emissions Zone parameters and operational status
		  ○ Traffic conditions
		  ○ Environmental conditions
		  ○ Road weather conditions
		  ○ Multi-modal travel options
		  ○ Performance measures
		  ○ Archived data
		  ○ Operator inputs (e.g., creating Low Emissions Zone, code red air quality alerts, or adding new equipment (e.g., new RSE units) to the system)
			Individual Vehicles
			• DLEZS-DP-08: Detect Violations for Individual Vehicles
			• DLEZS-DP-09: Manage Electronic Payment Processing
			• DLEZS-D-01: Disseminate Low Emissions Zone Parameters to vehicles
			• DLEZS-D-02: Disseminate Low Emissions Zone Parameters to Other Centers and Travelers
			• DLEZS-D-03: Disseminate Traffic Conditions to Other Centers and Travelers
			• DLEZS-D-04: Disseminate Traffic Conditions to Vehicles
			• DLEZS-D-05: Disseminate Multi-Modal Travel Options
			• DLEZS-D-06: Disseminate Environmental Conditions to Other Centers and Travelers
			• DLEZS-D-07: Disseminate Environmental Conditions to Vehicles
			• DLEZS-D-08: Request for Electronic Payment to Individual Vehicles
			• DLEZS-D-09: Request for Payment from Financial Institutions
			• DLEZS-D-10: Provide Incentives
			• DLEZS-D-11: Provide Confirmation of Payment or Incentives to Vehicles

ID	ACTORS	DATA FLOW / ACTION	RELATED USER NEEDS
			• DLEZS-D-12: Provide Notice of Violation to Vehicles • DLEZS-D-13: Notify Enforcement Agencies of Violations • DLEZS-DA-01: Archive Low Emissions Zone Data • DLEZS-DA-02: Archive Financial Data • DLEZS-DA-03: Determine Performance Measures • DLEZS-UI-01: User Interface

Actor and System Definitions

- **Connected Vehicle Roadway Equipment (includes RSE, cell tower, and Satellite)** | The Connected Vehicle Roadway Equipment actor includes the RSE units distributed on and along the roadway. These devices are capable of both transmitting and receiving data using DSRC radios, using the 5.9 GHz band approved for DSRC use by the FCC. The devices may also support other wireless communications, such as cellular and Wi-Fi communications. RSE units support the appropriate IEEE and SAE standards (IEEE 802.11p, IEEE 1609 family, and SAE J2735). The Connected Vehicle Roadway Equipment Actor also includes local processing capabilities to support processing of data at the roadside.

- **Driver** | The Driver actor represents the human entity that operates a licensed vehicle on the roadway. Included are operators of private, transit, and commercial vehicles where the data being sent or received is not particular to the type of vehicle. Thus, this actor originates driver requests and receives driver information that reflects the interactions which might be useful to all drivers, regardless of vehicle classification.

- **Dynamic Low Emissions Zone System** | The Dynamic Low Emissions Zone System is a computerized transportation system that employs communication technology to gather traffic and environmental information from multiple sources including ITS Roadway & Payment Equipment, Connected Vehicle Roadway Equipment, and other systems. The system then processes these data and determines whether a Low Emissions Zone should be created or decommissioned for an area, along a corridor, or for a region. Data considered in the creation or decommissioning of a Low Emissions Zone includes real-time and predicted traffic and environmental conditions, location and duration of special events, or other data. Once the Low Emissions Zone is created, parameters of the Low Emissions Zone would be established including the location of the zone, criteria for vehicles entering the zone, and fee structures for entering the zone. The Dynamic Low Emissions Zone System evaluates traffic and environmental parameters for an area in real-time and adapts to fluctuating traffic and environmental conditions. The system also predicts future traffic and environmental conditions using historical data and real-time data. This allows the system to predict future problem areas. Together, these features allow the system to readily adapt to actual and predicted traffic volumes and environmental conditions so the traffic network operation is optimized to reduce emissions. The Dynamic Low Emissions Zone System also supports the collection of fees from vehicles entering the Low Emissions Zone or the determination of incentives for vehicles leaving the zone. For example, the system may be set up to have travelers: (a) pay for entering the Low Emissions Zone, preferably using connected vehicle electronic toll collection technology or (b) receive an incentive (e.g., partial or full fee rebate, credit that can be applied to Low Emission Zone fees in the future) for green transportation choices while driving in the Low Emissions Zone. The system considers criteria

such as the type of vehicle, engine type, and emissions profile of the vehicle as it approaches or enters the Dynamic Low Emissions Zone to determine fees. Incentives may be determined based on the amount of time the vehicle spent in the Low Emissions Zone, mileage driven within the zone, or amount of emissions emitted while in the zone. Traveler information is another major component of the Dynamic Low Emissions Zone System, especially considering the dynamic aspect of the Low Emissions Zones being proposed. Traveler information includes providing travelers with the geographic limits and criteria for the Low Emissions Zone. The system allows this information to be disseminated to travelers using conventional ITS technologies such as DMS, traveler information websites, mobile phone applications, as well as connected vehicle technologies that would allow travelers to receive information about the Low Emissions Zone through in-vehicle systems.

- **Emissions Management Center (Other Centers)** | The Emissions Management Center actor provides the capabilities for air quality managers to monitor and manage air quality. These capabilities include collecting emissions data from distributed emissions sensors within the Roadway actor and from Vehicle actors, and ingesting regional air quality data from external sources and sensors such as operated by the National Weather Service (NWS) or the EPA. These sensors monitor general air quality for an area and also monitor the emissions of individual vehicles on the roadway. The sector emissions measures are collected, processed, and used to identify sectors exceeding or predicted to exceed pre-defined pollution levels. This information is provided to Traffic Management actors to implement strategies intended to reduce emissions in and around the problem areas. This actor provides any functions necessary to inform the violators and otherwise ensure timely compliance with emissions standards. This actor may co-reside with the Traffic Management actor or may operate in its own distinct location depending on regional preferences and priorities.

- **Enforcement Agencies (Other Centers)** | The Enforcement Agencies actor represents the systems that receive reports of violations detected by various ITS facilities including individual vehicle emissions, toll violations, excessive speed in work zones, etc.

- **Event Promoter (Other Centers)** | The Event Promoter actor represents special event sponsors that have knowledge of events that may impact travel on roadways or other modes. Examples of special event sponsors include sporting events, conventions, motorcades/parades, and public/political events. These promoters interface to the ITS to provide event information such as date, time, estimated duration, location, anticipated number of attendees, and any other information pertinent to traffic movement in the surrounding area.

- **Financial Institution (Other Centers)** | The Financial Institution actor represents the organization that handles all electronic fund transfer requests to enable the transfer of funds from the user of the service to the provider of the service. The functions and activities of financial clearinghouses are subsumed by this entity.

- **Information Service Provider (Other Centers)** | The Information Service Provider actor collects, processes, stores, and disseminates transportation information to system operators and the traveling public. The actor can play several different roles in an integrated ITS. In

one role, the ISP provides a data collection, fusing, and repackaging function, collecting information from transportation system operators and redistributing this information to other system operators in the region and other ISPs. In this information redistribution role, the ISP provides a bridge between the various transportation systems that produce the information and the other ISPs and their subscribers that use the information. The second role of an Information Service Provider is focused on delivery of traveler information to subscribers and the public at large. Information provided includes basic advisories, traffic and road conditions, transit schedule information, yellow pages information, ride-matching information, and parking information. The subsystem also provides the capability to provide specific directions to travelers by receiving origin and destination requests from travelers, generating route plans, and returning the calculated plans to the users. In addition to general route planning for travelers, the Information Service Provider also supports specialized route planning for vehicle fleets. In this third role, the ISP function may be dedicated to, or even embedded within, the dispatch system. Reservation services are also provided in advanced implementations. Both basic one-way (broadcast) and personalized two-way information provision are supported. The ISP is most commonly implemented as an Internet web site, but it represents any traveler information distribution service including systems that broadcast digital transportation data (e.g., satellite radio networks) and systems that support distribution through I2V communications networks. The ISP accomplishes these roles using constantly evolving technologies like the Internet (World Wide Web pages), direct broadcast communications (email alerts, pagers, satellite radio network data broadcasts), communications through I2V communications networks, etc.

- **ITS Roadway & Payment Equipment** | The ITS Roadway & Payment Equipment actor includes the equipment distributed on and along the roadway that monitors and controls traffic and monitors and manages the roadway itself. Equipment includes traffic detectors, environmental sensors, traffic signals, highway advisory radios (HARs), DMSs, CCTV cameras, and video image processing systems, grade crossing warning systems, and freeway ramp metering systems. HOV lane management, reversible lane management functions, and barrier systems that control access to transportation infrastructure such as roadways, bridges, and tunnels are also supported. This actor also provides the capability for environmental monitoring including sensors that measure road conditions, surface weather, and vehicle emissions. In adverse conditions, automated systems can be used to apply anti-icing materials, disperse fog, etc. This actor also represents the roadway components of a toll collection, VMT, congestion charging, and other systems that support payment from a vehicle. As a toll collection system, this subsystem provides the capability for vehicle operators to pay tolls without stopping their vehicles. It supports use of locally determined pricing structures and includes the capability to implement various variable road pricing policies. Each transaction is accompanied by feedback to the customer indicating the general status of the customer account.

- **In-Vehicle System** | The In-Vehicle System resides in the vehicle and is used to collect, process, and disseminate data to various actors. A major function of the In-Vehicle System is to collect information about the Dynamic Low Emissions Zone, as well as traffic and environmental conditions, and present this information to the driver to assist him or her in making informed pre-trip and en-route travel choices. This

information may include the location of the Dynamic Low Emissions Zone, the fee structure for entering the zone, or restrictions for entering the zone. Additionally, the In-Vehicle System may present drivers with information about traffic conditions within the Low Emissions Zone or trip/route options through or around the Low Emissions Zone. For example, the driver should be presented with multi-modal options for entering the Low Emissions Zone and/or with alternate routes around the Low Emissions Zone. Another key function of the In-Vehicle System is to collect emissions data from vehicle diagnostic systems or other on-board sensor and to disseminate these data to Connected Vehicle Roadway Equipment. These data would be used by the Dynamic Low Emissions Zone System – located at a center – to determine when a Low Emissions Zone should be established or decommissioned based on real-time environmental conditions data. They would also be used to help determine the fee structure for the Low Emissions Zone. The In-Vehicle System facilitates the payment of fee when a vehicle enters or incentives (e.g., partial or full rebate) when a vehicle leaves a Low Emissions Zone. The In-Vehicle System facilitates payment of fees or collection of incentives similar to how electronic toll collection systems work today. However, data such as the vehicle's engine type or emissions may be used to determine a vehicle's fee. Higher emitting vehicles may be charged a higher fee to enter the zone than lower emitting vehicles. Likewise, vehicles driving more in the Low Emissions Zone may receive no or a lesser incentive than vehicles driving less in the zone. Criteria may be established to allow people living inside the Low Emissions Zone to enter and drive within the zone at a lesser fee or no fee. To deter higher emitting vehicles from entering the Low Emissions Zone, data need to be collected directly from vehicles so that a fee can be determined for individual vehicles. The time or mileage driven within the Low Emissions Zone and a vehicle's driving style within the zone (e.g., adherence to eco-driving tactics) may also be used to determine incentives or rebates for vehicles as they leave the zone. For example, the Dynamic Low Emissions Zone System may collect the time or vehicle's mileage when it entered the Low Emissions Zone and when it exited the Low Emissions Zone. Additionally, the In-Vehicle System may provide data about the amount of emissions emitted while in the zone. These data may be used by the Dynamic Low Emissions Zone System to determine if a rebate or incentive should be given to the vehicle. Vehicles driving less and emitting fewer emissions may receive a financial incentive when they leave the zone. Incentives may be provided through I2V communications back to the vehicle or sent directly to the financial institution.

- **Operator** | The Operator actor represents the human entity that directly interfaces with the Eco-Traffic Signal System.
- **Other On-Board Sensors** | The Other On-board Sensors Actor represents sensors that may be installed on vehicles to collect traffic or environmental conditions data. For example, sensors may be equipped on a vehicle to measure atmospheric, surface (i.e., pavement and soil), and/or hydrologic conditions.
- **Vehicle** | The Vehicle actor provides the sensory, processing, storage, and communications functions necessary to support efficient, safe, and environmentally efficient travel. Both one-way and two-way communications options, including 5.9 GHz band approved for DSRC use by the FCC and other wireless communications such as cellular, support a spectrum of information services. This capability allows the vehicle

actor to disseminate information about its status (i.e., current speed, acceleration, braking, and average emissions) to other vehicles or to the Connected Vehicle Roadway actor. Advanced sensors, processors, enhanced driver interfaces, and actuators in the Vehicle actor complement the driver information services so that, in addition to making informed mode and route selections, the driver travels these routes in a safer and more consistent manner. This Actor may also include more advanced functions that assume limited control of the vehicle to maintain safe headway.

- **Traffic Management Center (Other Centers)** | The Traffic Management Center actor monitors and controls traffic and the road network. It represents the functionality provided by centers that manage a broad range of transportation facilities including freeway systems, rural and suburban highway systems, and urban and suburban traffic control systems. This actor communicates with the Roadway actor to monitor and manage traffic flow and monitor the condition of the roadway, surrounding environmental conditions, and field equipment status (e.g., traffic signals). This actor also manages traffic and transportation resources to support allied agencies in responding to, and recovering from, incidents ranging from minor traffic incidents through major disasters. The Traffic Management actor supports HOV lane management and coordination, road pricing, and other demand management policies that can alleviate congestion and influence mode selection. The actor communicates with other Traffic Management actors to coordinate traffic information and control strategies in neighboring jurisdictions.

- **Vehicle Diagnostic System** | The Vehicle Diagnostic Systems actor represents computer-based systems, located on vehicles, designed to monitor the performance of some of an engine's major components including those responsible for controlling emissions.

- **Vulnerable Road User** | Non-motorized road users, such as pedestrians and cyclists as well as motor-cyclists and persons with disabilities or reduced mobility and orientation Vulnerable road users